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THE METEOROLOGICAL PROBLEM OF THE NORTH ATLANTIC

By F. Entwistle, B.Sc.

(*Summary of Lecture delivered before the Royal Aeronautical Society, on November 3rd,* 1938.)

Meteorology has always been regarded as an essential adjunct to the safe, regular and economical operation of an air route but whereas, along the shorter overland routes, such as those which form a close network over Europe, radio direction-finding stations and blind flying equipment have resulted in pilots being able to fly largely independent of weather conditions (apart from the danger of ice accretion and the weather at the terminals), meteorology has become an increasingly important factor in the operation of trans-ocean routes. In addition to the risk of overlong flying times, due to unexpected head winds, an error in wind estimation might result in the aircraft drifting badly off its course in several hours. Direction-finding assistance, both from shore stations and from ships, is of considerable importance but over long ranges a comparatively small error in bearings can produce a dangerously large position error. It follows, therefore, that meteorology enters into the problem of *navigation* over long trans-ocean routes, accurate wind forecasts being of great importance.

Over the North Atlantic there are three alternative routes: the northern route via Iceland, Greenland and Labrador; the direct route via Ireland and Newfoundland; and the southern route via the Azores and Bermuda. The northern route has a maximum stage of 900 miles but both the others entail non-stop flights of 2,000 miles (figure 1). The choice of a particular route depends largely on the meteorological conditions at possible air bases and

refuelling stops as well as those along the route itself. On the northern and direct routes the main meteorological considerations are fog, snow, ice accretion and the freezing of harbours in winter. These considerations preclude the operation of either of these routes by flying boats except during the summer half-year. Provided, however, that it is found possible to keep the runways at the Newfoundland airport clear of snow in winter, and the ice accretion problem can be overcome, it should be possible to operate the direct route with landplanes throughout the year. The southern route experiences better weather conditions than either of the other two routes but investigation has shown the Azores to be devoid of any flying boat base suitable for operation under all conditions of wind and weather. Unless this difficulty can be surmounted, it may be found that the only feasible means of operating the southern route is by landplanes, in which case the direct route, being shorter, would be preferable.

SUMMARY OF TIMES OF PASSAGE AND GROUND SPEEDS OF TRANS-ATLANTIC AIRCRAFT WITH AIR SPEED OF 150 M.P.H.

Route.	I.	II.		III.	
	Foynes to New York *via* Greenland.	Foynes to New York *via* Botwood.	Section Foynes to Botwood.	Foynes to New York *via* Azores.	Section Azores to Bermuda
Average of all times of passage (hrs.)	24·7	23·4	14·8	30·5	15·1
Corresponding ground speed (mi/hr.)	146	137	135	137	136
Average head wind (mi/hr.)...	4	13	15	13	14
Shortest time (hrs.)	18·6	17·6	10·0	22·7	11·1
Corresponding ground speed (mi/hr.)	194	177	200	184	185
Average following wind (mi/hr.)	44	27	50	34	35
Longest time (hrs.)	31·4	32·6	22·2	41·3	21·8
Corresponding ground speed (mi/hr.)	115	98	90	101	89
Average head wind (mi/hr.)	35	52	60	49	61
Percentage number of occasions corresponding to head wind of more than 40 mi/hr.	—	1·2	2·8	0·9	2·3
Number of days a year ...	—	4	10	2	8

The prevailing westerly winds over the North Atlantic, which attain their maximum speed in winter, stand out, however, as a predominating influence in the operation of any route in an east-west

direction. The more important results of an investigation into the times of passage of an aircraft cruising at 150 mi/hr. along the three routes from east to west are shown in the accompanying table. The northern route stands out as being the best from the point of view of wind, the average head wind being only 4 mi/hr. A remarkable

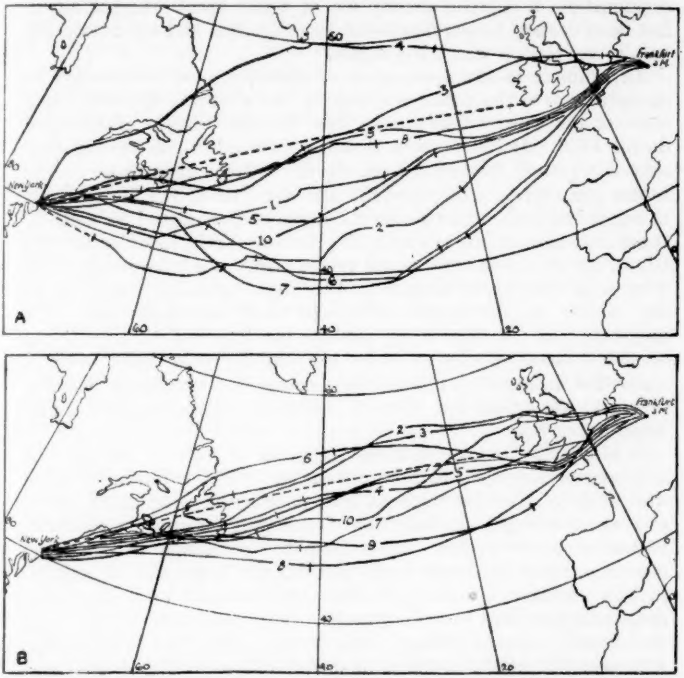

FIG. 2. MAPS SHOWING COURSES FOLLOWED BY THE AIRSHIP *Hindenburg* BETWEEN FRANKFORT AND NEW YORK, MAY TO OCTOBER, 1936.
A. OUTWARD FLIGHTS. B. RETURN FLIGHTS.

feature of the other two routes is the close agreement between the two long trans-ocean sections, Foynes–Botwood and Azores–Bermuda, the average head wind over these sections being of the order of 15 mi/hr. and the average maximum head wind 60 mi/hr. An average head wind exceeding 40 mi/hr. would be experienced on only 10 days a year on the direct route and on 8 days a year on the southern route. These data have an important bearing on the design of aircraft for the operation of a trans-Atlantic air route.

The specialised meteorological organisation which has been drawn up for flights on the direct route involves close co-operation between the forecasting centres at the Shannon and Botwood terminals,

both of which draw weather charts, covering the North Atlantic and adjacent continental areas, at six-hourly intervals, from data disseminated in accordance with international arrangements. The information supplied to Commanders of aircraft before departure and during flight is based on the analysis of these charts. The organisation, a detailed description of which space will not allow, has been devised to provide essential safeguards and the maximum help to navigation which is possible.

An example of the application of meteorological information to navigating over the ocean is shown by the charts in figure 2 which indicate the courses followed by the ill-fated airship *Hindenburg* during 1936. It can be seen that the outward flights showed considerably greater deviation from the direct track than those on the return journey. An outstanding case was that of the fourth flight in which the airship flew across the north of Ireland to just south of Greenland and thence via Labrador to New York, in order to take advantage of the easterly winds to the north of a low-pressure area lying over the North Atlantic. This flight actually proved to be the fastest of the series. Although such deviations are more practicable in the case of an airship, the Imperial Airways flying boat *Caledonia*, during a trans-Atlantic flight in 1937, made a somewhat similar deviation to avoid strong head winds, and thereby saved, in the estimation of the Commander, about two and a half hours flying time.

It is equally important, from the point of view of saving time and economising fuel, to take advantage of the variation of wind with height. Here the trans-Atlantic pilot is somewhat handicapped at present, owing to the difficulty of arranging for upper wind observations over the ocean. Apart from the possibility of equipping certain ocean-going liners with pilot balloon apparatus, a solution to this problem appears to be the establishment of a stationary meteorological ship in mid-Atlantic. The experience gained with the French ship *Carimaré*, which was stationed between the Azores and Bermuda in the summers of 1937 and 1938, showed that considerable help to trans-Atlantic flying can be secured in this way. The meteorological staff of the *Carimaré* made regular surface, pilot balloon and radio-sonde observations, and collected observations from ships which would not otherwise have been received, in addition to the regular meteorological collective messages issued from both Continents. By this means complete weather charts of the North Atlantic were prepared. The ship was also fitted with radio direction-finding equipment. The value of such a ship on the direct North-Atlantic route, about mid-way between Ireland and Newfoundland cannot be over-estimated. Apart from providing direct aids to navigation, it would supply data, particularly upper air information, which would ensure a more detailed analysis of the Atlantic weather situation and so improve the value of the information supplied to the flying services.

Estimating the Remoteness of Observed Cloud Features

By H. H. Lamb.

Visibility is normally better in the free air than near the earth's surface. The light rays whereby one sees distant cirrus, altostratus or tall cumulus, pass for most of the distance through layers of the atmosphere far above any surface haze. In the account of Watkins' 1930 Greenland expedition a case is mentioned where cumulus clouds were seen beyond a headland known to be 250 miles away. Inasmuch as the observation was made from an aircraft, this gives an unfair idea of the clearness of polar air in its source region when compared with surface observations of visibility in other parts of the world. Probably it is not uncommon for clouds of sufficient height to be seen from over 100 miles away in most parts of the British Isles. Indeed Mr. C. S. Durst, after seeing from near Bedford a rift in the sky over Cardigan Bay at sunset, discussed this aspect of the subject in an earlier paper in the *Meteorological Magazine.**

There must therefore be occasions on which a knowledge of the distance away of observed features of the visible sky would help in interpreting the weather map, and give a continuity to the weather reports from the surrounding stations situated underneath the sky in sight. The line of a front might be deduced from the distances obtained for several points along the edge of its cloud-sheet, the movement of the front from successive observations through time of this edge. Such observations may be of particular value at coastal forecasting stations, where reports from the neighbouring sea are few, or when for any other reason reports from the vital direction are lacking. At Montrose, for instance, it has been found possible to place fronts even over the further side of the North Sea by this means, to forecast the advance of warm fronts and return of cold fronts from the seaward quarter. The method gives a better idea of the actual rate of advance of a front than can be got from the isobars on the weather map. On occasion it also serves to foretell the time of arrival of showers as cumulo-nimbus clouds approach or of a general clearance by watching the movement of far-off rifts in an overcast sky.

The angle of elevation of a cloud (ε) in terms of its height (H) above sea level and its distance away (D), both in miles is given by :—

$$\tan \varepsilon = \frac{2RH - D^2}{2RD}$$

where R is the radius of the earth in miles. The observations are taken to be made from sea level.

The curves shown in Fig. 1 are derived from this formula and drawn to a logarithmic scale of distance to give the angles of elevation of

* *Meteorological Magazine*, 1928, page 241.

clouds at heights of 1, 2, 3, 4 or 5 miles seen from a station at sea level. Calculation shows that, if used at stations up to 500 feet above sea level, the curves will give an error in distance never more than 5 miles. The elevation error will be less than 1° except for low clouds near the station. Probably refraction effects produce as great an error, and the curves can fairly be used by any forecasting station in the British Isles.

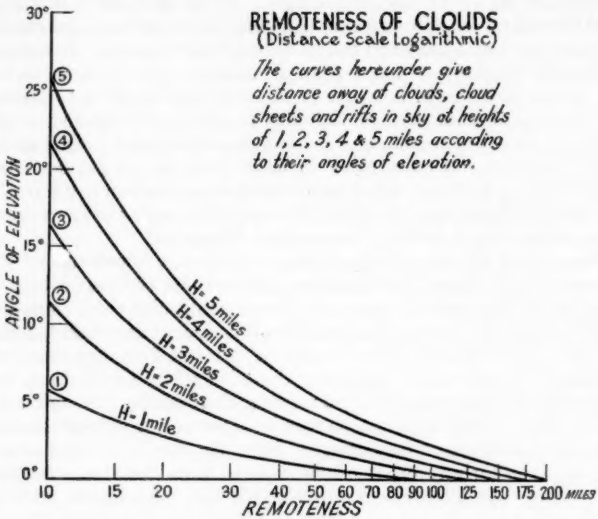

FIG.1

The curves can readily be used if displayed on the wall of the forecasting room. At stations which make pilot balloon observations with a theodolite it is only a moment's work to take the angle of elevation of a cloud feature (and its azimuthal direction). It remains to determine the height of the cloud feature observed. When cloud-sheets are continuous with cloud overhead, or which has lately passed overhead, it is often possible from pilot balloon observations to know the height rather accurately. But an experienced observer can usually tell the height of sheets of middle and high cloud to the nearest mile (no greater accuracy is required); whilst the tops of cumulus and cumulonimbus are estimated from their stage of development or by reference to where they pierce altocumulus layers.

Visibility on the West Somerset Coast

By T. F. Twist

The visibility conditions observed in the Bristol Channel on July 17th, 1937, and described in this Magazine for September, 1937, are of much interest. I should say from my experience (extending over more than 30 years) of the west Somerset coast that these conditions are far from uncommon, particularly during the summer months. I have never had the opportunity of seeing, as it were, a panoramic view of the conditions from the Welsh coast, but often have observed them both from the land at sea-level and the tops of the hills at over 1,000 feet, as well as from the sea on the Somerset side.

It seems that the relatively poor visibility over the sea is confined to within about 5 miles of the west Somerset and north Devon coast bordering the Exmoor country, as visibility in the low-lying land areas, such as occur at Porlock and between Minehead and Watchet, is quite good on these occasions, though the haze can be seen quite clearly out to sea from these points. From the hills it is possible to see over the top of the haze, and the coast and mountains of Wales are often very clear. The height of the haze naturally varies on different occasions, but seems usually to be between about 400 and 800 feet. The small cumulus-like clouds appear to be mainly in three overlapping lines, which would look from a distance such as from the Welsh coast, as one more or less continuous line of cloudlets. The points of origin of the lines are the Quantock Hills, the western portion of the North Hill near Minehead, and the Foreland near Lynmouth. These strings of cloudlets stretch away to windward from these points for six miles or more, as I have observed from boats while fishing.

These conditions only occur when the wind has veered from some southerly point to between west and west-north-west, the strength of the wind being usually about force 4. In the southerly current the visibility is usually good along the coast, except for deterioration caused by rain or drizzle.

It is noticed that the surface wind on the Glamorgan coast was west-south-west about 10 mi/hr. on July 17th; but on the Somerset side it was definitely west-north-west 15 mi/hr. or more and extended up to 800 feet at least, as I observed on the occasion in question. This veer and freshening of the wind along the west Somerset and north Devon coast is a common occurrence, while at a distance of five miles or so off-shore the wind backs and decreases in velocity. It is connected with the normal sea-breeze effect for this coast, augmented by deflection along the high coast line.

On July 17th the air behind the cold front was old maritime polar air which was probably fairly stable in its lowest layers owing to a long journey over the sea from the southward. In these conditions it would not differ greatly in its lowest layers from the air it was

displacing as evidenced by its high humidity and by fog reported at Pembroke and Scilly after the passage of the cold front. It would, however, differ from the displaced air at higher levels above the relatively stratified portion at the bottom, and it seems that the haze may be due to mixing in this bottom portion of the air in the sea-breeze area, and the cloudlets at the top formed by the larger eddies under the influence of the ranges of hills mentioned above. The distance of influence of these hills, especially the Quantocks, is remarkable, but from observations taken at sea it appears that the cloudlets are definitely connected with the deflection of the air-stream by these hills.

OFFICIAL NOTICE

Discussions at the Meteorological Office

The meetings for the discussion of recent contributions to meteorological literature will be resumed at the Meteorological Office on January 16th, 1939. The meetings will be held on alternate Mondays, promptly at 5 p.m. Tea will be available from 4.30 p.m. The dates and subjects for discussion are as follows :—

January 16th.—(1) *The trade wind inversion.* By H. von Ficker. *Berlin, Veröff. Met. Inst. Univ.*, **1**, Heft 4, 1936, pp. 33. (2) *Note on the heat exchange within the trade wind circulation.* By H. von Ficker, *Berlin, Sitzb. Ak. Wiss. Phys. Math. Kl.* 1936, **XI**, pp. 103–114. (Both in German.) *Opener*, Prof. D. Brunt.

January 30th.—*Investigations of selected European cyclones by means of serial ascents. Case* 4, *Feb.* 15–17, 1935. By J. Bjerknes and E. Palmen. *Oslo, Geofys. Publ.*, 12, *No.* 2, 1937, pp. 62. *Opener*, Mr. J. Crichton.

February 13th.—(1) *A contribution to the study of weather processes in the Gulf of Mexico, in the Caribbean Sea and in the West Indies. Met. Zs.* **54**, 1937, *Teil I and II*, pp. 353–359, *Teil III*, pp. 413–417. (2) *On the origin of West Indian hurricanes. Met. Zs.* **55**, 1938, pp. 317–321. Both by H. Externbrink. (In German.) *Opener*, Mr. S. Proud.

February 27th.—*On high clouds.* By W. Schwerdtfeger. *Berlin, Wiss. Abh. Reichs Wetterd.* **5**, No. 1, 1938, pp. 34. (In German.) *Opener*, Mr. H. W. L. Absalom.

March 13th.—Subject to be announced later. *Opener*, Mr. G. R. Hay.

A meeting of the staff of the Meteorological Office only will be held on March 27th.

Royal Meteorological Society

A meeting of the Society was held on Wednesday, the 16th instant, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. J. Glasspoole, M.Sc., Vice-President, was in the Chair.

The following papers were read and discussed.

S. Mal, M.Sc., Ph.D., D.I.C., and B. N. Desai, B.A., LL.B., M.Sc., PH.D., F.R.S.E.—(i) *The mechanism of thundery conditions at Karachi.*

Weather conditions and aeroplane ascents at Karachi between June 22nd and July 2nd, 1936, have been examined for understanding the mechanism of thundery conditions which prevailed there during that period. It is observed that thundery conditions occurred when the characteristic monsoon inversion was absent and there was a sufficiently deep layer of air which when raised to a certain level either by insolation, arrival of sea air, or convergence of winds, released an appreciable amount of energy of latent instability.

G. Manley, M.A., B.Sc.—On the occurrence of snow-cover in Great Britain.

Hitherto little information has been available with regard to the frequency of snow-cover on the uplands and mountains of Great Britain. Variations with altitute are very great, variations from year to year are also very great; few highland stations are available, while their records are often brief and interrupted. Further, the interpretation, analysis and criticism of the existing data with regard to snow-lying are difficult, and are only to be undertaken after a close survey of the environment and other features of the reporting stations, of which the majority are on low ground.

A relationship has now been derived between the mean temperature of the winter months and the average frequency of occurrence of snow-lying, which after test appears to be generally applicable to any given place over a period of years. It is necessary, however, to allow for several additional factors, notably quantity of snowfall which influence the duration of snow-cover. It appears that, making these allowances, a reasonable estimate can be made of the frequency of snow-cover at the majority of places in Great Britain; also, of the extent to which the expectation of snow-cover varies with small fluctuations in mean winter temperature over a period.

The Buchan Prize of the Royal Meteorological Society for 1939 has been awarded to Mr. E. W. Hewson, M.A., Ph.D. for the following papers contributed to the *Quarterly Journal* of the Society during the years 1933–1937;

"The application of wet-bulb potential temperature to air mass analysis, I",

Ditto, II. "The ascent of air at warm fronts",

Ditto, III. "Rainfall in depressions."

Correspondence

To the Editor, *Meteorological Magazine*

The Effect of Wind on the Temperature of a Thermometer

The *Meteorological Magazine* for September, 1938 contains a discussion between Colonel Gold and myself on the reading of a thermometer placed in a high velocity air stream. I think it is worth pointing out that the views I expressed there have now received experimental confirmation in all respects save one, namely, the magnitude of the error. On this latter point no information is available.

W. F. Hilton, in the *Proceedings of the Royal Society*, **A**, **168**, pp. 43–56 (October, 1938) gives the results of an experimental investigation into this matter. Concerning the circular cylinder, he states (p. 54): "The front of a cylinder registers very nearly the adiabatic compression temperature of the air stream. . . . . The thermocouple placed at the back, however, registers within 10 per cent. of the true temperature of the moving air stream in which it is placed. Thus on a circular cylinder are to be found almost the extreme ranges of temperature possible on a body in a moving air stream. The circular cylinder is therefore a most unsatisfactory shape for the thermometry of moving fluids, since the temperature taken up by the element will be function of the conductivity of the thermometric element, and of the temperature distribution round the cylinder."

The above results are identical with these suggested by me from theoretical considerations, but they leave open the question of the mean temperature of the thermometer bulb. In view of the importance of this problem, it seems highly desirable that the magnitude of the error be investigated, either by using two aircraft, as suggested by Colonel Gold, or by mounting the thermometer on a high speed whirling arm. O. G. SUTTON.

Experimental Station, Porton, Wilts, November 25th, 1938.

I am glad Mr. Sutton has drawn attention to Hilton's interesting experiments on the temperature distribution around a circular cylinder in a rapidly moving air stream. But I do not think that Hilton's results could reasonably be regarded as support for the view expressed by Mr. Sutton in his original letter that "the reading of a thermometer of conventional shape would not differ vastly from the true temperature of the air even at the speed of a modern aeroplane."

They suggest rather that the difference would be somewhere between the adiabatic effect and half that effect, i.e., between 11° F. and 5½° F. at a speed of 250 mi/hr.

Some observations with strut thermometers exposed in the manner described in my note in the *Meteorological Magazine* for September showed a difference of 3·2° F. between the readings when the aeroplane's speed was 80 mi/hr. and when it was 160 mi/hr. The

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CIRRUS CLOUD BELOW ALTO-CUMULUS ROLLS, MARCH 11TH, 1938, 17H. 5M.

(Looking west from Meteorological Office, Edinburgh)

theoretical difference on the hypothesis of adiabatic compression is 3·5° F.

I might mention that Dr. A. A. Griffiths pointed out about 9 years ago that the circular cylinder was theoretically an unsuitable form for a thermometer bulb moving with high velocity relative to the air, if the axis of the cylinder was transverse to the airstream because of the difficulty of computing theoretically the correction to the reading necessary on account of the motion of the air.

E. GOLD.

Meteorological Office, London, W.C.2, December, 7th 1938.

Cirrus Clouds

I was much interested in the article by Mr. Mirrlees in the *Meteorological Magazine* for November, 1938. One should not too readily assume that the most typical of all cirriform features, namely the long threads, usually with vertical extension, can be produced by water drops. Snow only commences to melt when the wet bulb temperature exceeds the freezing point, and soft hail can fall for a considerable distance before it melts. Even when the illumination is such that the threads are black, the distinction between hail or snow and rain is usually quite clear.

As regards *cirrus uncinus*, the usual explanation is that of falling snow in a region of marked variation of wind with height, and this fits in with the idea of rising currents causing the showers. Whether the particles rise or fall must depend on the vertical velocity of the rising air, and on that of the particles through the air. Generally the snow flakes would fall, and the cloud heads, which consist of much smaller particles, often apparently of super-cooled droplets, would often rise. In Mr. Clarke's photograph, published as fig. 4 with Mr. Mirrlees' article, there is a typical appearance of super-cooled droplets above ice crystals. The most natural explanation of a thread is that the fall of a large particle through the air sets up small eddies and tends to drag another particle into its wake. Straight horizontal threads near the horizon may be a perspective effect.

C. K. M. DOUGLAS.

Meteorological Office, London, December 2nd, 1938.

The low "cirrus" of March 11th, 1938, described by Mr. Cruickshank,* was also seen in Edinburgh and I enclose a photograph taken from a window of the Meteorological Office. The main mass of cirrus, part of which is seen to the left of the photograph, was very dense (as is evidenced by the lack of halation round the sun) and appeared to be much lower than the alto-cumulus rolls in the centre. The clouds in the upper right hand corner resembled cirro-cumulus but showed faint iridescence.

F. E. DIXON.

Meteorological Office, Edinburgh, November 24th, 1938.

* *Meteorological Magazine*, November, 1938, page 267.

The Prediction of Minimum Temperature on Clear Days

In a letter in the *Meteorological Magazine* for October, 1938, page 237, Mr. L. A. Ramdas refers to a formula which I gave some years ago for the total amount of long-wave radiation downward from a clear sky, and states that Raman showed "by actual computations" that my formula should be regarded as an approximation to Ångström's formula. What Raman did was to show that $b\sqrt{e}$ and $0{\cdot}28\ (1 - 10^{-0{\cdot}055e})$ can be made to agree over a wide range of values of e by a suitable choice of the constant b. We might therefore say with equal justification that what Raman did was to show "by actual computations" that Ångström's formula is an approximation to mine.

I have never seriously regarded either Ångström's formula or my own as more than an empirical formula. Now an empirical formula can only be judged on two bases, its simplicity, and the accuracy with which it represents the facts. My formula has two constants and Ångström's has three, and a square root is easier to handle than an antilogarithm. In my paper on this subject (*Q.J. Roy. Met. Soc.* **58,** 1932, p. 379), I showed that my formula gave a more accurate representation of certain observations than did Ångström's formula. So far as I can ascertain from his writings on this subject, Mr. Ramdas has made no such tests of accuracy of representation of observations with Ångström's formula, which would appear to be the normal method of deciding between two empirical formulae. The deduction of Ångström's formula on the basis of the assumption of certain mean values of the absorption coefficient within certain ranges of wave length can scarcely be regarded as conclusive. We might set against this the deduction by Pekeris and Elsasser of a formula involving the square root of the mass of absorbing material, a deduction which involves no assumption so uncertain physically as that of a mean absorption coefficient.

My investigation of the representation of observations of long-wave radiation from the atmosphere by an empirical formula showed that each series of observations requires different values of the constants in the formula. This will be true no matter which of the two formulæ in question is used, and in practice it turns out to be rather a troublesome matter to compute the values of the constants required to fit Ångström's formula to any given series of observations. D. Brunt.

Imperial College of Science and Technology, October 31st, 1938.

The Sound of Lightning

It is possible that the swish occasionally heard with lightning is due to a brush discharge which may occur just before the flash, and may occur at various places round about, and not actually or only where the flash strikes. In a correspondence in *Nature* some years ago a ship's captain described hearing the noise, which at first he took

to be a boat cover being ripped off; he heard it a number of times and each time it was before and not after the flash. It was I think Mr. J. S. Dines who suggested that whatever it is that causes the swish occurs before the flash but that most people perceive it as occurring after because a bright light may affect the brain more quickly than a not very loud sound.

A case that occurred here seems to point to the fact that the swish may originate at more than one point. Two men were working in a field when a farm was struck about 400 yards away, the men were working about 150 yards apart; each heard the swish coming apparently from nearby trees, a holly in one case, an oak in the other. The trees in both cases were in the opposite direction from the farm; one man said that when he looked up he expected to see the tree in flames. C. J. P. CAVE.

Stoner Hill, Petersfield, October 30th, 1938.

Sunspots and Seasonal Weather

For the past fifty years I have been carefully investigating the possibility of a definite effect of sunspot periods on seasonal weather in the British Isles with the following results.

The year 1895 (*i.e.*, the winter of 1894–5) may be said to have ended a period of cold winters with one of the most severe on record; a note in *Symons's Meteorological Magazine* by me refers to frost having frozen the six-foot driving-mains of the (then) Lambeth Water Co., at a depth of some 4 ft.

After this, cold winters have recurred at alternate 12 and 10 year periods, *viz.*: 1906–7, 1916–17, 1928–9. Therefore, assuming that this sequence continues, the coming winter 1938–9 should be a severe one in January and February, as the 10 year period makes such a winter due. Colour is lent to this idea from the fact that most of our cold winters are preceded by abnormally mild Octobers and early Novembers as in this year.

In any case it will be interesting to note if the sequence holds good over the 45 years (approx.) which, I believe, is a crucial period in weather cycles. DONALD W. HORNER.

Telford Lodge, Manor Road, Weston-super-Mare, November 8th, 1938.

Lunar Corona Observed on November 2nd, 1938

A fine lunar corona was observed at North Finchley, North London, by me at 19h. 15m. G.M.T. The aureole appeared yellowish green in colour bounded on the outside by a brownish red ring. Surrounding the aureole was another coloured ring but this appeared as a circular rainbow, red on the outside shading to yellow and green to blue and violet on the inside. At the time the sky was clear except for some cirrus clouds which stretched over the sky and across the moon.

J. MONGER.

Woodside Park, N.12, November 3rd, 1938.

Night Radiation in the Spring of 1938

From data obtained during the past two years from radiation thermometers at Goff's Oak, Herts, night radiation during the spring months (March to May) of this year seems to have been very active, compared with the corresponding period in the year 1937.

Curves showing the mean deviation of night minima of radiation thermometers, at various levels, from screen minima during the spring of the past two years are shown in Fig. 1. It will be seen

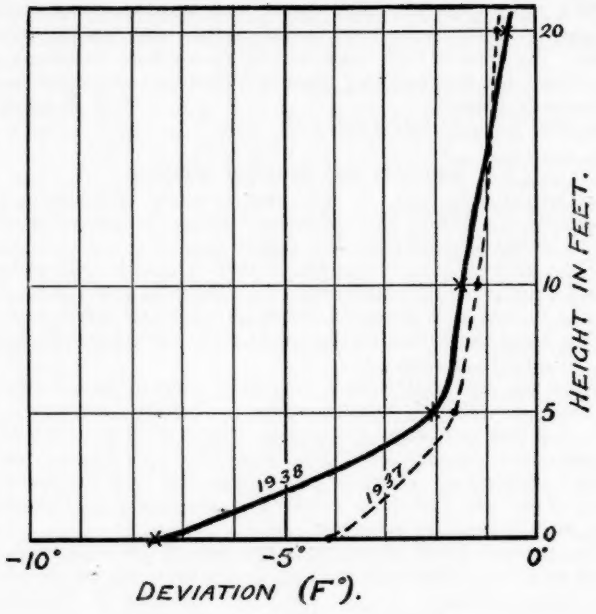


Fig. 1.

that the grass minimum in spring, 1938 averages 7·8°F. below the screen minimum, against a corresponding figure of 4·2°F. in the previous year. Above five feet the differences are negligible.

The difference between the grass minimum and that in the screen exceeded 10°F. on 30 nights in the spring of 1938, and on the night of May 9th to 10th reached the exceptional figure of 14·4°F. On the night of March 3rd to 4th the difference at five feet from the soil was as great as 4·0°F. The greatest difference at 10 ft. was 2·4°F. on the night of May 16th–17th. and on the previous night the difference at 20 ft. was 1·9°F. Differences exceeding 1·5°F. at 20 ft. were recorded on five nights. From these figures it would

seem that night radiation during the past spring has been exceptionally high, and it would be of interest to know if this was general throughout the country, or peculiar to south-east Hertfordshire.

DONALD L. CHAMPION.

Meteorological Station, Goff's Oak, Herts, November 8th, 1938.

Duststorms in Iraq

In addition to the many interesting references to this type of phenomenon mentioned by Mr. Durward in the May issue of this Magazine, may I point out that such a storm furnished the background, as pointed out by Dr. W. Emery Barnes (" A New Commentary on Holy Scripture," S.P.C.K., 1928) for the " call " of the prophet Ezekiel. The relevant passage (Ezekiel I, 4) reads :—

> " And I looked, and behold, a stormy wind came out of the north, a great cloud with a fire infolding itself, and a brightness round about it, and out of the midst thereof as the colour of amber, out of the midst of the fire."

Commenting on this passage, Dr. Barnes says, " In this narrative natural phenomena and spiritual perceptions are mixed so that they can hardly be separated." (Here he quotes Col. Chesney's account, given by Mr. Durward) " Such a storm in its suddenness, its sombre glory and its sudden cessation might well suggest to the prophet the intervention of an enraged and angry Deity."

This must be the earliest reference to such a storm extant for the call of Ezekiel came in 593 B.C. CICELY M. BOTLEY.

Guildables, 17, Holmesdale Gardens, Hastings, May 20th, 1938.

The Formation of Cloud from Rising Steam

At 7h. 10m. on August 11th, a small cumulus cloud was observed developing on the top of a column of smoke and steam rising from the chimneys and condensers of Broomgrove electricity power station which lies due west and at a distance of about 1,000 yards from my observation point. The surface wind at the time was calm. The cloud began to form a little below 2,000 feet and extended upwards to at least 3,000 feet. Although the surface wind was calm the smoke and steam was rising rapidly up to the base of the cloud due, no doubt, to the convection caused by heat from the chimneys and the relatively hot water in the condenser towers. As the cloud slowly moved away from the area it dispersed and other small patches of cloud formed, but were more in the nature of fracto-stratus. The general movement of the clouds was from south-east. There was no similar cloud at the time anywhere else, though there were developing patches of alto-cumulus at 6,000 feet moving from 155° at 11 miles per hour. Cumulus clouds did not appear until a little before 9h. when they soon assumed towering masses. Cumulo-nimbus was seen developing to north-north-east

at 13h. and this moved extremely slowly from an easterly point. Similar slight cloud formations have been observed from time to time as the result of rising steam from the power station (nearly always in the early morning with calm air), but they never assumed tall and well developed cumuli as that observed on this particular day. A. E. MOON.

39, Clive Avenue, Clive Vale, Hastings, 15th August, 1938.

NOTES AND QUERIES

The Calculation of Height with a Slide Rule

It may not be widely realized, even in meteorological circles, how easy it is to calculate the height of a pressure contour above sea level with an ordinary 10-inch slide rule.

The height Z is given by

$$Z = \frac{RT}{g} \log_e \frac{P_0}{P_z}$$

This we may write as

$$Z = K\, T_m \log_{10} \frac{P_0}{P_z}$$

where T_m is the mean temperature (°A) of the layer of atmosphere and

$K = 66 \cdot 1$ to give geodynamic height.
$= 67 \cdot 4$ to give height in metres
$= 221$ to give height in feet.

Thus, if the pressure at the top of the layer (P_z) is set on Scale C against the pressure at the bottom of the layer (P_0) on Scale D, in any units, as desired, then by turning over the slide rule $\log \frac{P_0}{P_z}$ is given on the L scale.*

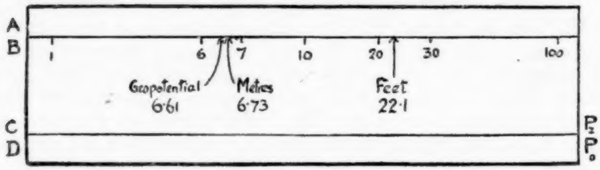


FIG. 1

This reading L is multiplied on Scale A by the mean temperature (T_m) on Scale B and then by setting figure 10 on Scale B against the product on Scale A the rule is ready to give without further adjustment—

geopotential on Scale A against 6·61 on Scale B
or height in kilometres against 6·74
or finally height in thousands of feet against 22·1.

This procedure applies strictly to an isothermal layer and with little error to a layer having a constant lapse rate: with an

* On some slide-rules, a slight variation of this step is necessary.

irregularly varying lapse rate, the atmosphere is divided into suitable layers, preferably by plotting a T log P curve.

Then $H = Z_1 + Z_2 + Z_3$ ....

$$= \Sigma K\, T_m \log \frac{P_1}{P_2}$$

Reduction of Barometer Readings.—Conversely pressure difference can be easily calculated, for if the height is known, divide it on Scale A by T_m and K consecutively on Scale B. The final dividend is $\log \frac{P_o}{P_z}$; by setting this reading on the log scale at the back of the rule, Scales C and D on the front of the rule are automatically set to read off P_z or P_o respectively in any desired units; either P_z or P_o will be known and the other read off. R. M. POULTER.

Whirlwind at Kirton, Lincs., Nov. 18th, 1938

The following account of a whirlwind at Kirton, a village four miles south of Boston, has been received from Mr. N. H. Middlebrook, of Freiston Road, Boston :—

"On the night of Nov. 18th, 1938 before the occurrence of the whirlwind a very strong wind, accompanied by heavy rain, was blowing. At about 23h. 50m. a terrific roar was heard, lasting nearly five minutes. The whirlwind affected a strip about 150 yards wide and did most damage in Station Road, Kirton. One resident informed me that his house trembled and shook and that all kinds of articles, such as chicken huts, were hurtling through the air. Several windows were blown in, hundreds of slates were torn from roofs, and pieces of masonry removed. Large sheets of corrugated zinc were carried for considerable distances, one piece finishing its journey across some telephone wires. A large new building had most of its roof and many of its windows removed. A man who was driving at the time informed me that his car was twice turned completely round in the road."

Sir Thomas Hudson Beare

Sir Thomas Hudson Beare who is now 79 years of age enters this session on his 50th year as a professor. Twelve of those years were spent in London University and the other 38 in Edinburgh where he has been Regius Professor of Engineering. During that period Sir Thomas has been closely identified with some of the most important developments of the University including the planning and erecting of the great series of new science buildings on the south side of the city.

Sir Thomas has been a contributor of rainfall records to British Rainfall since 1906 and of complete climatological records from 1910 to the Scottish Meteorological Society and afterwards to the Meteorological Office. An evaporation gauge has also been maintained at the Engineering Department. For two years Sir Thomas Hudson Beare represented the University of Edinburgh on the Advisory Committee of the Meteorological Office, Edinburgh.

The Gale of November 23rd, 1938

A severe gale swept the greater part of the British Isles on November 23rd. It was associated with an intense depression moving northeast across the country, the position at 7h. being shown on the accompanying chart. The gale was specially severe in the Pembroke area, and at St. Ann's Head a gust reached 108 mi/hr. at 8h. 5m.,

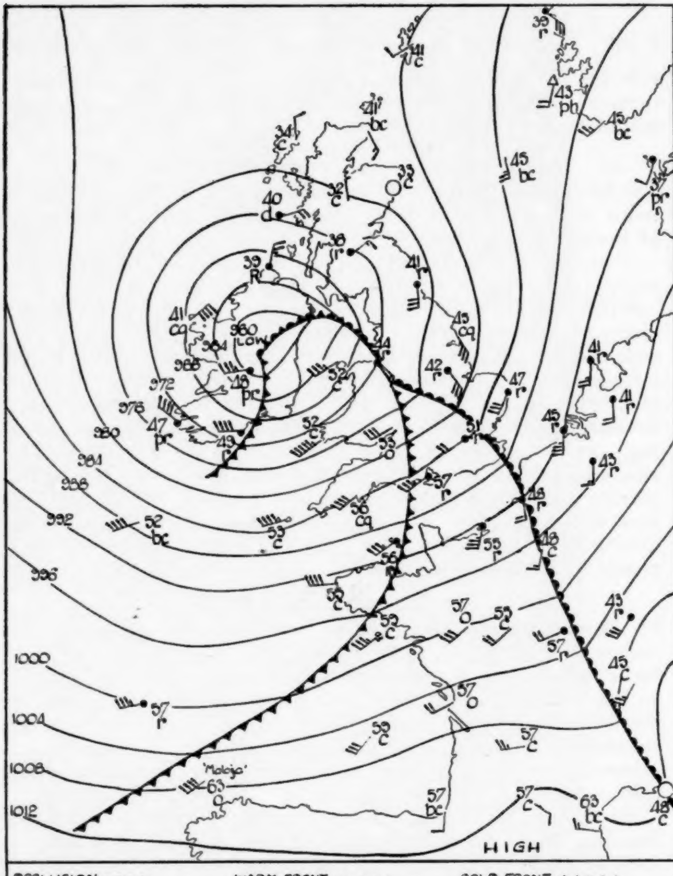


Fig. 1.—7h., November 23rd, 1938

closely followed by one of 107 mi/hr. at 8h. 15m. and of 106 mi/hr. at 9h. The velocity of 108 mi/hr. is among the highest yet recorded in the British Isles, but it must be kept in mind that the anemometer at St. Ann's Head has only been installed for four years, that the site is on an exposed headland with a cliff on its west side, and that the anemometer head is 70 feet above the ground.

Other notable gusts were 85 mi/hr. at Valentia at 2h. 55m., 83 mi/hr. at Birmingham at 13h. 50m. (remarkable for an inland station) and 82 mi/hr. at Lympne at 13h. 2m. As usual with severe storms, the strongest winds occurred after the first cold front had passed. There were indications of a minor cold front near Roches Point at 7h., and this would have reached Pembroke at the time of the highest gusts. The rate of travel of the depression was about 45 mi/hr., and the air on the south side was travelling much faster, averaging probably 90 mi/hr. at 2,000 feet, so that any minor fronts inevitably travelled round the trough.

Mr. C. J. Griffiths

On the retirement in November, 1938, of Mr. C. J. Griffiths, for nearly 30 years engineer to the Thames Conservancy Board, it is appropriate that we should refer in this Magazine to his interest in the study of run-off in relation to the rainfall over the Thames basin. The Thames Conservancy has published, for many years, daily values of the flow at Teddington Weir, of the amount abstracted by the Metropolitan Water Board and Water Companies and of the total estimated " natural flow ". In addition estimates are given of the general rainfall over the area day by day.

Mr. Griffiths found that it was important to know quickly the rainfall over the area, in order to estimate the height likely to be attained by the river some hours later. He made arrangements accordingly to secure rainfall records by telephone and ascertained from past information how these records were likely to represent the rainfall over the Valley as a whole. Mr. Griffith's work in using meteorological data for this purpose is likely to be of assistance to engineers of other Catchment Boards. In view of his experience Mr. Griffiths was appointed a member of the Inland Water Survey Committee set up by the Ministry of Health and Scottish Office in 1935.

Mr. Griffith's successor as engineer to the Board is Mr. R. V. W. Stock, formerly assistant engineer.

Threatening Atmosphere in Russia

While appreciating the spirit of co-operation which leads the editors of some foreign meteorological journals to publish short English summaries of papers, we may perhaps allow ourselves the luxury of a smile at the following, from a recent Russian publication :—

" In this article are discussed the turbulent qualities of the atmosphere. Is pointed out the nonuniformity of structure of the

stratum of indignation by the height and is quoted its distribution on separate stratums, characterised by their structure."

The same publication also contains a paper bearing the English title :—

"About the limit of thickness of sea longevity ices."

Frequency of Ground Frosts; Effect of the Hour of Observation

The occurrence of a "ground frost" is determined from the reading of a "grass minimum" thermometer, set in the evening and read the following morning. A ground frost is said to occur if the corrected reading is 30·4°F. or lower. At ordinary climatological stations the reading is taken at 9h. G.M.T., but at "synoptic" stations the hour of morning observation is 7h. G.M.T. Since the temperature on the grass in winter has not always fallen to its lowest value by 7h., it is clear that the recorded frequency of ground frosts will be lower at a synoptic station than at a climatological station, where the climatic conditions are identical.

At certain stations the grass minimum thermometer has been read at 7h. and again at 9h. or 10h. From these records it is possible to determine how many ground frosts are in fact "missed" by the adoption of 7h. as the hour of reading at synoptic stations. The results for the single year 1926 at four observatories (Aberdeen, Kew, Valentia and Eskdalemuir) are given in an article published in the June, 1927 issue of this Magazine. They indicate that the omissions are negligible for practical purposes. At Aberdeen the 7h. readings gave 84 frosts and the 9h. readings 86; at the other observatories the numbers differed by one only.

Further information has now become available, tending on the whole to confirm the view that the frequency of recorded ground frosts is not seriously diminished by observing at 7h. instead of at 9h. At Kew, during the ten years 1928 to 1937 859 ground frosts were registered at 7h. as compared with 869 at 9h., a difference of only one per cent. Of the ten ground frosts missed at 7h., three occurred in January, five in November and two in December. For other stations the number of unrecorded ground frosts was as follows : Upper Heyford (Oxfordshire) 2 in 11 years; Sealand (Flint) 11 in 9 years; Mount Batten (Devon), 13 in 11 years; Cranwell (Lincs.) 4 in 5 years; Abbotsinch (Renfrew), 5 in 5 years; Aldergrove (Antrim) 6 in 11 years. On the other hand as many as five ground frosts were missed at 7h. at Manston (Kent) during the winter of 1937 to 1938, and at Abbotsinch (Renfrew), three were missed in the single month of December, 1937. E. G. B.

REVIEWS

Methoden und Probleme der Dynamischen Meteorologie. By H. Ertel. Ergebnisse der Mathematik und ihrer Grenzgebiste. Bd. 5. No. 3. 9½ inches × 6½ inches, pp. 122. Berlin. 1938.

In so far as the reviewer is competent to judge, this monograph will take its place as a valuable work of reference for the mathematical meteorologist. It is not altogether easy to decide in what category to place the treatment; it is certainly not intended as a formal text-book for the author has selected his field to his own taste with no claim to completeness. A substantial part of the work is merely a condensed presentation of papers by numerous writers. Unfortunately mathematics does not readily permit of brevity without omission of the assumptions and approximations, the discussion of which is usually the core of the matter. This is particularly well illustrated in the last section, where the mathematical bases of ideas due to Scherhag, to Brunt and Douglas, to Stüve and Mügge, and to Ertel himself are all indicated without affording the reader any material upon which to judge their relative merits or with which to resolve their inconsistencies. There are 310 numbered equations, but the casual reader should be warned not to quote any one as carrying Ertel's certificate of validity without a careful reading of the context. No less than 246 references to the literature appear as footnotes to the text; the publication will therefore be of greatest value to the research student as a survey of the present position. The bibliography is such a vital part of the work that one regrets the omission of at least an index of authors.

How far mathematical analysis will lead to a solution of the outstanding problems of meteorology remains to be seen; real progress so far has been due more to the inspiration of the physicist and the synoptic meteorologist than to the abstruse labours of the mathematician. Indeed, if one excepts a few restricted problems it is not easy to point to any remarkable achievement involving more than a very moderate standard of mathematical analysis.

It has been said on good authority that it is possible to prove almost any absurdity in meteorology by mathematical argument, and the reviewer imagines he could illustrate this thesis from Ertel's paper. But, in spite of this, the non-mathematical meteorologist is as great a danger in the land as the non-meteorological mathematician. The physics of meteorology is with few exceptions within the grasp of anyone with a scientific education, but there are many pitfalls for the unwary; it is the dynamics which is difficult, and many of our popular conceptions will not stand the acid test of expression in mathematical form. It may be hoped that the new recruits to the science possessing the necessary mathematical equipment will not fail to apply themselves critically to the outstanding problems. Ertel's survey should prove a stimulating introduction.

R. C. Sutcliffe.

Meteorology as a Career. The Institute of Research, Chicago. No. 84. 11 inches × $8\frac{1}{2}$ inches, pp. 20. *Illus.* Chicago. 1938.

This is an interesting and well printed pamphlet published for the purpose of informing young people and their parents in the United States of the prospects of meteorology as a profession. Full details are given not only of the duties and emoluments of the various grades of employment, but also of the high school and college training necessary before the candidate can hope to begin his career. The unattractive as well as the attractive features of meteorological work are frankly set forth, and the anonymous author is obviously well informed. All will agree with the following, under the heading " Personal Qualifications Necessary " :—

> " To scientific ability must be added a passion for the truth and the willingness to exert painstaking effort in verifying the accuracy of observations and researches in his field " ;

and also with the following :—

> " A forecaster is subjected to continuous 'kidding' from other persons about his forecasts and possible mistakes. A worrying type of person will soon succumb to the continuous psychological stress of whether or not a forecast will turn out right."

From the details given in the pamphlet one forms the impression that meteorology is being handled in the United States in a characteristically " go-ahead " manner, to meet the rapidly growing needs of aviation, forestry and other services.

E. G. B.

BOOKS RECEIVED

The law of storms in the China Sea. By C. W. Jeffries and G. S. P. Heywood. Royal Observatory, Hong Kong, 1938.

Some comparisons of the invigorating effect of the climate in different parts of New Zealand. By W. A. Macky (No. 18).

Visibility and upper winds at Auckland, Wellington and Christchurch. By L. N. Laisen (No. 20).

Climatological observations at Eastbourne, Wellington, and some comparisons. By W. A. Macky (No. 21). New Zealand ; Dept. of Sc. and Ind. Res. Met. Office Notes, Wellington, 1937–1938.

The Weather of November, 1938

The northern North Atlantic was occupied by an intense area of low pressure, centred over Iceland where the mean of 990 mb. was 12 mb. below normal. Pressure was normal (1021 mb.) over the Azores, and 5 mb. above normal at Bermuda and in the Mediterranean, so that the south–north pressure gradient over the Atlantic and western Europe was abnormally steep. The prevailing strong westerly winds

made the north very mild over the whole of western and central Europe. The mean temperatures were 35° F. to 40° F. in Scandinavia, 45° F.–52° F. in the British Isles, about 45° F. in central and south-eastern Europe and 55° F. to 63° F. in the Mediterranean, the difference from normal ranging from zero in Scotland to + 5° F. in England, France and Germany and Scandinavia and 10° F. in Finland. In Canada pressure and temperature differed little from normal except in the far north-west, where low pressure over the Arctic Ocean gave temperatures a few degrees above normal. Rainfall was abnormally heavy on the western coasts of Europe, but farther east it was below normal in most places.

The weather of the month in the British Isles was exceptionally mild; at Wakefield and Ross-on-Wye it was the mildest November on record, while at Oxford, in a record which goes back to 1815, the mean temperature, 49·3° F., was the highest for November since 1818. At a number of stations the maximum temperature on the 5th was the highest on record in November. Winds from between south and west predominated and the month was wet on the whole; at Eskdalemuir and Renfrew the total rainfall was the highest recorded in November since readings were first taken in 1910 and 1921 respectively. The duration of sunshine was very variable; for example, at Chester (Sealand) it was the sunniest November on record and at Eskdalemuir it was the dullest. A widespread and unusually severe gale occurred on the 23rd; the wind speed in a gust rose to 108 m.p.h. at St. Ann's Head Pembroke.

On the 1st and 2nd a deep depression off the north of Scotland moved north-north-east while an associated trough of low pressure moved eastward over the British Isles; gales occurred in the west and north on the 1st and 2nd, and moderately heavy rain in northern districts on the 1st. Local thunderstorms were reported in Scotland and northern England and snow locally in Scotland. On the 3rd and 4th Atlantic depressions moved north-east and heavy rain fell at a number of places in the west and north on the 3rd. Between the 5th and 15th an anticyclone moved north-east from Spain to central Europe and then eastward to Russia; meanwhile Atlantic depressions moved north-east or north along our western seaboard. This pressure distribution caused a flow of unusually mild equatorial air over the British Isles; from the 1st–19th widely separated stations had a mean temperature more than ten degrees Fahrenheit above their respective averages for November, while Tottenham had a positive deviation of 14·3° F. and Sealand 14·2° F. Heavy rain fell at times in the west and north; on the 12th, for example, 3·54 in. was registered at Troutbeck, Cumberland, 3·50 in. at Borrowdale, Cumberland, and 2·50 in. at Ballynahinch Castle, County Galway. A deep depression situated to the north of Scotland caused gales in the north and west and considerable rain generally on the 18th and 19th; a gust of 98 m.p.h. was registered at Stornoway, in the northern Hebrides, on the 18th.

Subsequently, from the 20th onwards, depressions moved more directly over the British Isles; lower temperatures prevailed and rain fell frequently. On the 23rd an intense depression moved rapidly north-east from Ireland to southern Norway causing wide-spread and severe gales over the British Isles. Cool northerly winds prevailed in the rear of this depression. Wintry precipitation occurred locally at times in the north between the 19th and 28th, snow being reported to be lying to a depth of 4 in. on high ground in southern Scotland on the 23rd. Local thunderstorms were reported between the 17th and 20th, and 23rd and 30th. Secondary depressions moving north-east over the country caused heavy rain, particularly in southern districts during the 24 hours ending at 9 a.m. on the 26th; 2·91 in. fell at Totnes, 2·35 in. at Holne, Devon, and 2·26 in. at Ipplepen Vicarage, Devon.

The distribution of bright sunshine for the month was as follows:—

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	30	−16	Chester ..	89	+36
Aberdeen ..	74	+15	Ross-on-Wye	73	+10
Dublin	83	+12	Falmouth ..	53	−23
Birr Castle ..	56	− 5	Gorleston ..	62	− 4
Valentia ..	36	−27	Kew.. ..	62	+ 9

Kew temperature, mean, 49·7°F.: diff. from average, +5·4°F.

Miscellaneous Notes on Weather Abroad

As a result of warm weather many Alpine passes were reopened to traffic early in the month, and ascents of the Matterhorn and the Kempfisch Horn, near Zermatt, were made—a feat hitherto regarded as impossible. Great damage was done by gales on the south-west coast of France, and heavy rainstorms caused floods in northern Italy on the 22nd. A severe storm was encountered in the Bay of Bengal by the long-distance flight aeroplanes on the 8th, the airscrew being surrounded by St. Elmo's fire at the height of the storm. During a thunderstorm at Aziz, near Aleppo, on the 9th, eight persons were reported killed and 60 houses damaged. Floods were experienced in Batavia on the 29th; many landslips and much damage resulted and 65 natives lost their lives. The first snowstorm of the season was reported from Newfoundland on the 4th and from many parts of the United States on the 7th, while in New York State and Maryland, shade maxima of 76° F. were recorded. A cold wave followed and at Syracuse on the 24th, 19° of frost were reported. Snow and fog accompanied the low temperatures resulting in a death roll from accidents of over 50. Fourteen inches of snow fell in New York City from the 24th–27th. Heavy rains during the month are thought to be a partial cause of the mountain split in St. Lucia on the 21st. A further landslip which buried many of the

injured and the rescuers brought the total loss of life to 75. Gales, reaching 90 miles per hour at times, caused damage to shipping around Nova Scotia on the 27th : the storm was followed by unusual warmth. An aeroplane was blown out to sea and smashed on rocks near San Francisco during a gale on the 27th. Drought conditions are reported from Victoria. Many wheat crops have failed entirely, and all are very bad.

The Times, November 4th–30th, 1938.

Daily Readings at Kew Observatory, November, 1938

Date	Pressure, M.S.L. 13h.	Wind, Dir., Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain	Sun	REMARKS
	mb.		°F.	°F.	%	in.	hrs.	
1	1004·3	W. 4	49	56	47	0·10	4·9	r–r_0 4h.–7h. & 8h.–9h.
2	1007·3	WSW. 4	42	54	61	trace	5·6	pr_0 14h.
3	1015·4	SW. 2	47	55	69	—	0·1	
4	1014·8	SW. 3	52	61	81	trace	0·1	pr_0 1h. & 15h.
5	1023·5	WSW. 3	57	66	77	—	7·3	
6	1024·4	SW. 3	55	57	90	trace	0·0	id_0 8h.–12h. & 21h.
7	1018·4	SW 2	53	56	89	trace	0·0	id_0 8h.–13h. & 17h.
8	1017·1	SW. 2	49	55	75	trace	0·0	d_0 12h., f 23h.–24h.
9	1017·7	SE. 3	43	51	80	—	0·0	f 0h.–1h.
10	1015·2	SE. 2	49	58	78	—	4·3	
11	1006·5	SE. 3	48	62	68	0·08	4·8	r–r_0 15h.–17h.
12	1012·4	S. 5	52	61	82	0·09	1·0	ir_0–r 7h.–12h.
13	1013·6	S. 4	57	61	84	0·04	0·0	ir_0–r 12h.–22h.
14	1024·8	SW. 2	55	59	73	0·01	2·0	pr_0 3h.
15	1030·4	SSW. 1	47	50	96	trace	0·0	f 6h.–19h., d_0 9h. & 21h.
16	1022·9	E. 2	47	55	93	0·04	0·0	r_0–r 7h.–9h. & 13h.–15h.
17	1023·3	SW. 2	52	54	78	0·01	0·1	r_0 2h.–3h., d_0 21h.
18	1019·9	S. 3	50	56	77	0·04	0·6	f 0h.–8h., r_0 21h.–23h.
19	1014·3	SW. 3	45	50	68	0·18	3·9	r–r_0 0h.–4h., pr_0 19h.
20	997·9	SSE. 4	43	51	87	0·61	0·0	r–r_0 3h.–7h. & 11h.–18h.
21	989·7	N. 2	37	43	94	0·01	0·0	f–F 8h.–24h., r_0 23h.
22	997·4	W. 3	39	47	66	trace	6·2	r_0 0h.–1h.
23	981·7	SW. 7	40	56	55	0·12	3·1	r–r_0 2h.–7h., pr_0 15h.
24	1004·8	W. 3	37	47	64	—	3·7	
25	1005·8	SW. 4	36	52	73	0·57	0·8	r_0 5h., r–r_0 19h.–23h.
26	1002·2	WSW. 3	46	48	68	0·33	5·2	r 0h.–4h.
27	1013·9	S. 3	32	47	69	0·01	4·6	f 9h., ir_0 16h.–17h.
28	1002·4	SSW. 2	47	49	96	0·26	0·0	r–r_0 0h.–5h., pr_0 16h.
29	1010·2	SW. 1	32	44	83	—	0·6	f 8h.–23h.
30	994·9	WSW. 4	34	52	67	0·10	3·0	r_0 5h.–7h. & 9h.–10h.
*	1010·9	—	46	54	76	2·60	2·1	*Means or Totals.

General Rainfall for November, 1938

England and Wales	141	per cent of the average 1881–1915.
Scotland	157	
Ireland	156	
British Isles ...	147	

Rainfall : November, 1938 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond .	Camden Square..........	2·98	126	*War* .	Birminghm, Edgbaston	3·40	143
Sur .	Reigate, Wray Pk. Rd..	4·29	137	*Leics* .	Thornton Reservoir ...	2·52	111
Kent .	Tenterden, Ashenden...	3·38	112	" .	Belvoir Castle............	2·33	104
" .	Folkestone, I. Hospital.	3·21	...	*Rut* .	Ridlington	2·51	109
" .	Margate, Cliftonville....	1·89	78	*Lincs* .	Boston, Skirbeck.........	1·83	92
" .	Eden'bdg., Falconhurst	4·13	116	" .	Cranwell Aerodrome...	1·83	98
Sus .	Compton, Compton Ho.	5·28	139	" .	Skegness, Marine Gdns.	2·17	100
" .	Patching Farm..........	4·13	116	" .	Louth, Westgate..........	2·65	103
" .	Eastbourne, Wil. Sq....	4·85	139	" .	Brigg, Wrawby St.......	2·08	...
Hants .	Ventnor, Roy.Nat.Hos.	4·81	150	*Notts* .	Mansfield, Carr Bank...	3·48	143
" .	Southampton,East Park	5·31	169	*Derby* .	Derby, The Arboretum	2·60	115
" .	Ovington Rectory.......	5·57	168	" .	Buxton, Terrace Slopes	6·44	138
" .	Sherborne St. John......	5·11	179	*Ches* .	Bidston Obsy..............	3·18	127
Herts .	Royston,Therfield Rec.	2·69	115	*Lancs* .	Manchester, Whit. Pk.	4·10	155
Bucks .	Slough, Upton............	3·09	139	" .	Stonyhurst College......	5·97	132
Oxf .	Oxford, Radcliffe.........	3·16	137	" .	Southport, Bedford Pk.	4·86	155
N'hant	Wellingboro, Swanspool	2·39	111	" .	Ulverston, Poaka Beck	7·55	136
" .	Oundle	1·68	...	" .	Lancaster, Greg Obsy.	6·05	152
Beds .	Woburn, Exptl. Farm...	2·34	104	" .	Blackpool	5·04	145
Cam .	Cambridge, Bot. Gdns.	1·90	98	*Yorks* .	Wath-upon-Dearne......	2·40	113
" .	March......................	1·98	97	" .	Wakefield,Clarence Pk.	3·06	144
Essex .	Chelmsford,County Gdns	2·95	131	" .	Oughtershaw Hall.......	10·54	...
" .	Lexden Hill House......	2·31	...	" .	Wetherby, Ribston H..	3·47	148
Suff .	Haughley House..........	2·02	...	" .	Hull, Pearson Park......	2·28	104
" .	Rendlesham Hall........	2·47	111	" .	Holme-on-Spalding......	2·82	129
" .	Lowestoft Sec. School...	2·48	106	" .	Felixkirk, Mt. St. John.	3·19	130
" .	Bury St. Ed., WestleyH.	2·85	124	" .	York, Museum............	2·55	122
Norf. .	Wells, Holkham Hall...	1·95	91	" .	Pickering, Houndgate...	3·15	127
Wilts .	Porton, W.D. Exp'l. Stn	4·60	176	" .	Scarborough...............	2·81	114
" .	Bishops Cannings........	3·54	124	" .	Middlesbrough............	2·32	109
Dor .	Weymouth, Westham.	5·21	168	" .	Baldersdale, Hury Res.	5·64	152
" .	Beaminster, East St....	7·13	180	*Durh* .	Ushaw College............	2·64	104
" .	Shaftesbury	3·94	122	*Nor* .	Newcastle, Leazes Pk...	2·71	115
Devon .	Plymouth, The Hoe....	8·36	229	" .	Bellingham, Highgreen	4·81	140
" .	Holne, Church Pk. Cott.	13·40	208	" .	Lilburn Tower Gdns....	3·47	104
" .	Teignmouth, Den Gdns.	6·17	193	*Cumb* .	Carlisle, Scaleby Hall...	6·75	225
" .	Cullompton	6·38	185	" .	Borrowdale, Seathwaite	20·50	160
" .	Sidmouth, U.D.C.........	4·80	...	" .	Thirlmere, Dale Head H.	16·41	169
" .	Barnstaple, N. Dev.Ath	6·32	161	" .	Keswick, High Hill......	11·33	200
" .	Dartm'r,Cranmere Pool	12·00	...	" .	Ravenglass, The Grove	8·14	182
" .	Okehampton, Uplands.	9·82	185	*West* .	Appleby, Castle Bank...	5·28	159
Corn .	Redruth, Trewirgie......	7·68	158	*Mon* .	Abergavenny, Larchf'd	5·64	148
" .	Penzance, Morrab Gdns.	7·96	174	*Glam* .	Ystalyfera, Wern Ho.....	11·21	171
" .	St. Austell, Trevarna...	8·39	170	" .	Treherbert, Tynywaun.	16·15	...
Soms .	Chewton Mendip..........	7·11	166	" .	Cardiff, Penylan..........	6·24	154
" .	Long Ashton............	5·18	163	*Carm* .	Carmarthen,M. & P. Sch.	11·77	229
" .	Street, Millfield..........	3·58	132	*Card* .	Aberystwyth	5·81	...
Glos .	Blockley	3·18	...	*Rad* .	BirmW.W.Tyrmynydd	10·58	159
" .	Cirencester, Gwynfa....	3·83	129	*Mont* .	Lake Vyrnwy	10·27	185
Here .	Ross-on-Wye.............	3·21	127	*Flint* .	Sealand Aerodrome......	3·24	138
" .	Kington, Lynhales.......	4·75	148	*Mer* .	Blaenau Festiniog	10·41	107
Salop .	Church Stretton.........	5·64	192	" .	Dolgelley, Bontddu......	7·63	123
" .	Shifnal, Hatton Grange	3·35	139	*Carn* .	Llandudno	2·81	97
" .	Cheswardine Hall........	3·82	147	" .	Snowdon, L. Llydaw 9..	22·95	...
Worc .	Malvern, Free Library...	3·01	119	*Ang* .	Holyhead, Salt Island...	5·96	144
" .	Ombersley, Holt Lock.	2·88	126	" .	Lligwy	7·52	...
War .	Alcester, Ragley Hall...	2·38	103	*I. Man*	Douglas, Boro' Cem....	5·31	113

Rainfall : November, 1938 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.Peter P't.Grange Rd.	5·36	128	*R&C*	Stornoway,C.GuardStn.	5·72	103
Wig	Pt. William, Monreith.	6·73	156	*Suth*	Lairg	3·65	91
„	New Luce School	6·76	132	„	Skerray Borgie	6·41	...
Kirk	Dalry, Glendarroch	10·60	177	„	Melvich	4·54	113
Dumf.	Eskdalemuir Obs	11·68	201	„	Loch More, Achfary	12·61	147
Roxb	Hawick, Wolfelee	7·65	198	*Caith*	Wick	2·80	89
„	Kelso, Broomlands	3·47	150	*Ork*	Deerness	4·39	112
Peeb	Stobo Castle	7·98	241	*Shet*	Lerwick Observatory	6·20	146
Berw	Marchmont House	4·23	141	*Cork*	Cork, University Coll	5·95	148
E.Lot	North Berwick Res	...	...	„	Roches Point, C.G. Stn.	5·78	138
Midl	Edinburgh, Blackfd. H.	4·46	199	„	Mallow, Longueville	5·67	152
Lan	Auchtyfardle	8·28	...	*Kerry*	Valentia Observatory	7·26	133
Ayr	Kilmarnock, Kay Park	6·10	...	„	Gearhameen	12·80	132
„	Girvan, Pinmore	7·82	147	„	Bally McElligott Rec	5·57	...
„	Glen Afton, Ayr San.	10·86	197	„	Darrynane Abbey	6·14	120
Renf	Glasgow, Queen's Park	7·93	213	*Wat*	Waterford, Gortmore	6·31	171
„	Greenock, Prospect H.	12·37	204	*Tip*	Nenagh, Castle Lough.	6·15	153
Bute	Rothesay, Ardencraig	10·31	203	„	Cashel, Ballinamona	5·20	150
„	Dougarie Lodge	7·86	150	*Lim*	Foynes, Coolnanes	5·70	140
Arg	Loch Sunart, G'dale	12·09	162	„	Limerick, Mulgrave St.	5·55	144
„	Ardgour House	18·93	...	*Clare*	Inagh, Mount Callan	9·92	...
„	Glen Etive	21·12	204	*Wexf*	Gorey, Courtown Ho	6·40	183
„	Oban	13·74	...	*Wick*	Rathnew, Clonmannon.	6·09	...
„	Poltalloch	11·82	210	*Carl*	Bagnalstown,Fenagh H.	5·22	156
„	Inveraray Castle	21·43	251	„	Hacketstown Rectory	5·79	149
„	Islay, Eallabus	9·27	172	*Leix*	Blandsfort House	5·96	178
„	Mull, Benmore	22·30	155	*Offaly.*	Birr Castle	4·68	151
„	Tiree	7·46	154	*Kild*	Straffan House	2·45	78
Kinr	Loch Leven Sluice	4·94	138	*Dublin*	Dublin, Phoenix Park.	2·54	90
Fife	Leuchars Aerodrome	3·39	148	*Meath.*	Kells, Headfort	4·58	135
Perth	Loch Dhu	15·65	180	*W.M*	Moate, Coolatore	4·65	...
„	Crieff, Strathearn Hyd.	7·79	179	„	Mullingar, Belvedere	5·16	151
„	Blair Castle Gardens	7·52	214	*Long*	Castle Forbes Gdns	5·95	165
Angus.	Kettins School	4·02	130	*Gal*	Galway, Grammar Sch.	6·36	156
„	Pearsie House	4·62	...	„	Ballynahinch Castle	17·10	286
„	Montrose, Sunnyside	3·68	139	„	Ahascragh, Clonbrock.	6·18	153
Aber	Balmoral Castle Gdns.	4·46	121	*Rosc*	Strokestown, C'node	6·52	192
„	Logie Coldstone Sch	2·86	93	*Mayo.*	Blacksod Point	10·60	203
„	Aberdeen Observatory.	2·68	91	„	Mallaranny	11·82	...
„	New Deer School House	2·62	78	„	Westport House	9·63	197
Moray	Gordon Castle	2·31	80	„	Delphi Lodge	19·19	184
„	Grantown-on-Spey	3·64	122	*Sligo*	Markree Castle	6·85	165
Nairn.	Nairn	3·06	130	*Cavan.*	Crossdoney, Kevit Cas.	5·64	...
Inv's	Ben Alder Lodge	10·24	...	*Ferm*	Crom Castle	6·26	180
„	Kingussie, The Birches.	5·38	...	*Arm*	Armagh Obsy	4·06	143
„	Loch Ness, Foyers	7·98	205	*Down.*	Fofanny Reservoir	11.07	...
„	Inverness, Culduthel R.	4·66	183	„	Seaforde	5.22	138
„	Loch Quoich, Loan	32·04	...	„	Donaghadee, C. G. Stn.	3.59	118
„	Glenquoich	24·26	200	*Antr*	Belfast,Queen's Univ	4.55	135
„	Arisaig House	9·96	148	„	Aldergrove Aerodrome.	4.06	125
„	Glenleven, Corrour	17·48	233	„	Ballymena, Harryville.	5.82	144
„	Fort William, Glasdrum	17·55	...	*Lon*	Garvagh, Moneydig	6.40	...
„	Skye, Dunvegan	12·99	..	„	Londonderry, Creggan.	7.47	182
„	Barra, Skallary	8·50	...	*Tyr*	Omagh, Edenfel	7.52	198
R&C	Tain, Ardlarach	3·65	113	*Don*	Malin Head	6.35	156
„	Ullapool	7·99	150	„	Dunfanaghy	7.40	179
„	Achnashellach	14·63	160	„	Dunkineely	8·45	...

Climatological Table for the British Empire, June, 1938

STATIONS.	PRESSURE. Mean of Day M.S.L.	PRESSURE. Diff. from Normal.	TEMPERATURE. Absolute. Max.	TEMPERATURE. Absolute. Min.	TEMPERATURE. Mean Values. Max.	TEMPERATURE. Mean Values. Min.	TEMPERATURE. Mean Values. ½ Max. and Min.	TEMPERATURE. Mean Values. Diff. from Normal.	TEMPERATURE. Mean Wet Bulb.	Relative Humidity	Mean Cloud Am'nt	PRECIPITATION. Am'nt.	PRECIPITATION. Diff. from Normal.	PRECIPITATION. Days	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	0–10	in.	in.			
London, Kew Obsy.	1017·2	+ 0·5	77	45	69·6	53·1	61·3	+ 2·3	53·5	72	7·3	0·35	− 1·80	7	6·9	42
Gibraltar	1017·1	− 0·2	88	60	76·2	64·2	70·2	− 0·3	63·5	80	3·7	0·04	...	2	...	...
Malta	1017·9	+ 2·7	87	61	79·6	66·6	73·1	+ 0·4	66·1	71	1·5	0·00	− 0·09	0	12·6	87
St. Helena	1019·3	− 0·7	70	54	64·7	57·2	60·9	+ 1·1	58·7	92	8·6	2·06	− 0·76	21	...	...
Freetown, Sierra Leone	1013·4	+ 3·1	87	68	84·7	73·0	78·9	...	75·3	83	7·3	13·33	− 6·71	24	...	...
Lagos, Nigeria	1013·2	+ 0·8	88	71	84·0	74·1	79·1	− 0·4	74·9	90	7·5	11·52	− 6·96	15	4·3	35
Kaduna, Nigeria	1011·8	...	93	66	89·2	68·9	79·1	+ 2·4	71·1	83	7·9	5·26	− 1·83	13	7·9	62
Zomba, Nyasaland	1019·1	+ 1·4	81	51	71·7	55·0	63·3	+ 0·4	59·8	80	6·2	0·56	+ 0·08	8	...	...
Salisbury, Rhodesia	1021·6	+ 0·2	77	39	68·2	44·7	56·5	− 0·4	49·5	60	3·7	0·12	...	1	6·9	62
Cape Town	1022·3	+ 2·2	86	35	69·1	49·3	59·2	+ 3·5	50·3	88	4·4	1·97	− 2·53	10	...	...
Johannesburg	1023·4	+ 1·6	66	33	60·6	43·3	51·9	+ 1·2	43·1	60	0·3	0·21	+ 0·07	2	8·1	77
Mauritius	1019·6	+ 0·8	78	57	75·4	63·3	69·3	− 0·1	65·5	72	3·8	0·85	− 1·56	12	8·6	79
Calcutta, Alipore Obsy.	999·5	− 0·2	96	77	90·0	79·8	84·9	− 0·2	80·5	85	8·6	9·15	− 2·76	13*	...	...
Bombay	1002·7	− 1·3	90	73	85·7	77·4	81·5	− 2·5	78·0	86	9·0	31·24	+ 11·37	26*	...	...
Madras	1003·4	− 0·4	100	74	95·6	79·6	87·6	− 2·4	75·0	62	8·4	1·85	− 0·12	6*	...	...
Colombo, Ceylon	1009·0	+ 0·4	87	73	86·1	78·7	82·4	+ 0·8	77·2	75	7·9	1·94	− 5·38	17	5·5	44
Singapore	1009·5	+ 0·6	89	71	87·3	77·5	82·4	+ 0·9	78·2	76	6·1	6·05	− 0·82	8	8·3	68
Hongkong	1007·1	+ 1·3	94	77	89·0	80·2	84·6	+ 3·2	79·3	76	5·8	2·99	− 12·71	11	8·7	65
Sandakan	1008·8	...	89	71	86·5	75·0	80·7	− 1·0	76·7	85	7·9	11·05	+ 3·55	16	...	...
Sydney, N.S.W.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Melbourne	1019·0	+ 0·5	63	33	56·5	43·9	50·2	− 0·2	45·4	80	6·6	4·02	+ 1·96	20	2·6	27
Adelaide	1020·6	+ 1·2	66	37	59·3	44·8	52·1	− 1·5	47·4	77	7·8	2·37	− 0·71	17	3·7	38
Perth, W. Australia	1023·5	+ 5·5	72	42	63·7	48·5	56·1	− 0·7	50·5	75	5·3	5·51	− 1·43	14	5·6	56
Coolgardie	1021·9	+ 3·0	74	35	58·9	42·3	50·6	− 2·2	46·7	81	4·7	1·19	− 0·07	5	...	...
Brisbane	1019·8	+ 1·5	77	41	69·0	51·6	60·3	+ 0·1	53·2	70	4·2	0·86	− 1·93	8	7·0	67
Hobart, Tasmania	1013·7	− 0·6	59	35	53·4	41·6	47·5	+ 0·5	43·3	77	5·6	4·08	+ 1·85	16	3·7	41
Wellington, N.Z.	1012·7	− 2·2	62	35	53·2	43·7	48·5	− 1·0	46·3	81	7·2	7·50	+ 2·73	18	3·2	35
Suva, Fiji	1013·3	− 0·3	86	65	80·9	70·9	75·9	+ 1·2	71·7	87	5·8	4·84	− 1·87	18	4·6	41
Apia, Samoa	1011·6	0·0	87	72	84·9	74·6	79·7	+ 1·9	75·7	79	4·8	3·74	− 1·61	17	7·9	70
Kingston, Jamaica	1014·6	+ 0·8	93	72	88·8	73·	81·2	− 0·1	72·2	75	3·8	2·29	− 1·81	4	6·8	52
Grenada, W.I.	1010·2	+ 3·1	89	71	86	73	79·5	+ 0·5	74	78	6	15·36	+ 7·11	22	...	...
Toronto	1015·4	+ 0·7	88	47	75·8	55·8	65·8	+ 2·0	58·2	72	4·9	1·49	− 1·17	13	7·7	50
Winnipeg	1014·0	+ 2·2	93	30	74·2	50·1	62·1	− 0·2	50·9	83	5·6	1·32	− 1·79	15	7·1	44
St. John, N.B.	1015·0	+ 1·5	82	45	65·8	50·3	58·1	+ 1·6	54·0	87	7·3	4·32	+ 1·05	19	6·1	39
Victoria, B.C.	1017·6	+ 0·8	77	45	65·7	49·7	57·7	+ 0·7	53·3	73	3·6	0·02	− 0·82	2	11·2	70

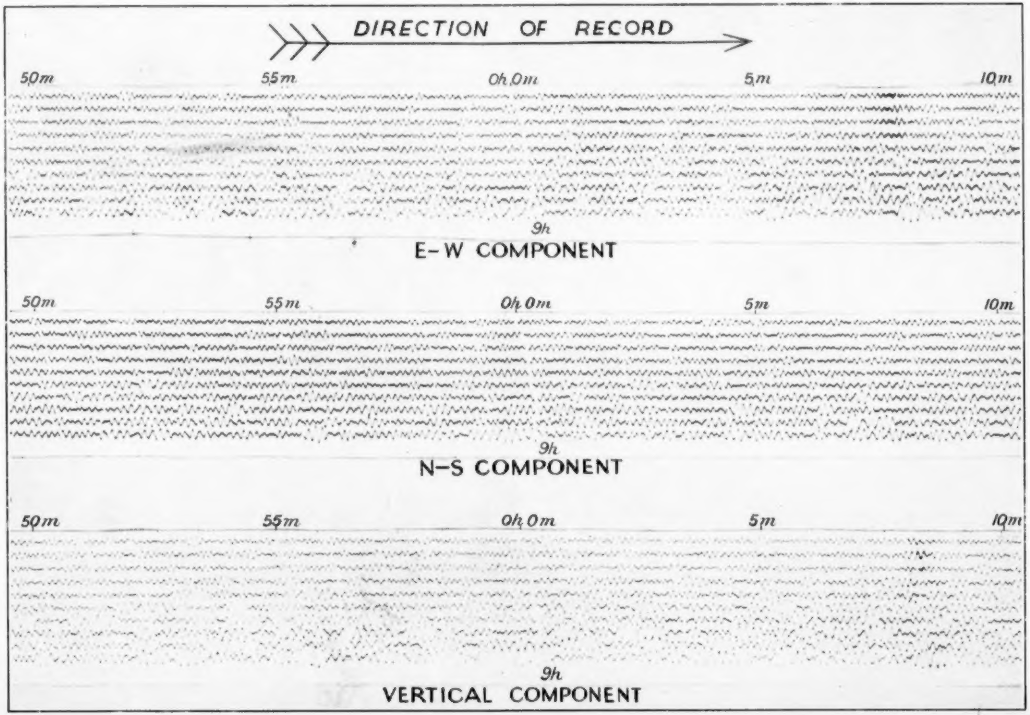
* For Indian stations [illegible]

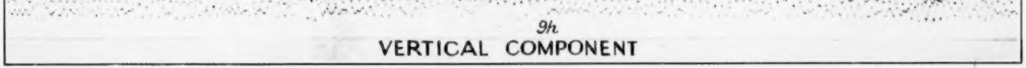
(44970) Wt. 21/31 1250 12/38 Hw. G.377/6

Toronto	1015·4	+ 0·7	88	47	75·8	55·8	65·8	+ 2·0	58·2	72	4·9	1·49	− 1·17	13	7·7	50
Winnipeg	1014·0	+ 2·2	93	30	74·2	50·1	62·1	− 0·2	50·9	83	5·6	1·32	− 1·79	15	7·1	44
St. John, N.B.	1015·0	+ 1·5	82	45	65·8	50·3	58·1	+ 1·6	54·0	87	7·3	4·32	+ 1·05	19	6·1	39
Victoria, B.C.	1017·6	+ 0·8	77	45	65·7	49·7	57·7	+ 0·7	53·3	73	3·6	0·02	− 0·82	2	11·2	70

* For Indian stations [illegible]

Frontispiece]

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VERTICAL COMPONENT